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COMBINING CONVENTIONAL SPINNING WITH WALL THICKNESS REDUCTION IN ONE PASS

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ABSTRACT

The thin wall cup products are largely used in industries, it is usually made by a conventional spinning process to produce the cup shape, followed by wall thickness reduction process (Flow Forming) to reduce the cup wall thickness. In the present work a new compound tool was developed to perform both processes of conventional and flow forming spinning in the same stroke. The new compound tool consists of two rollers to perform the conventional spinning process followed by two balls to perform the flow forming process at the same stroke. The rollers and the balls are mounted in the jaws of lathe four jaw chuck. The rollers are mounted on two opposite jaws at the same level. The balls are mounted on the other two jaws in another level following the rollers level by about five millimeters. The main advantage of the compound tool is reducing the product cost by reducing the manufacturing time by about 40%. The other advantage of the new compound process is that when comparing it to other processes like incremental forming or single point incremental forming we found that it does not need a special machine or a CNC machine, but it can be conducted on a conventional lathe machine. The new tool was experimentally tested by conducting many compound processes using the tool to produce a thin wall cup. The experimental work verified the success of the new tool.

KEYWORDS: Conventional Spinning, Ball Spinning, Flow Forming, Compound Spinning Tool & Thin Wall Thickness Cup

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Original Article

INTRODUCTION

Metal spinning is the process of forming a flat metal blank into the shape of the cup by means of manual or hydraulic tool as rollers. This process is performed by tension and compression forces effect on the blank at the same time to produce axisymmetric hollow parts (Heinz Tschaetsch 2004). The spinning process in its original type does not includes any intended thickness reduction.

The main types of spinning as mentioned by Boljanovic are manual or conventional spinning, shear spinning, and tube spinning (BOLJANOVIC 2004). Another classification of spinning process named the two types of power spinning and flow forming as types of spinning process(Bewlay 2006; Semiatin, Force, and Directorate 2005).

Many developments for the spinning process were conducted, mentioned here the Single Point Incremental Forming[SPIF]process which has the ability of forming asymmetric shapes and conducting a small wall thickness reduction relative to the draw angle at the same time (Jeswiet et al. 2005). Jeswiet et al. concluded

that SPIF process is a very successful process for the forming of asymmetric and complex shapes. But, this process requires a CNC machine and it still produces shapes with thickness inequality along the wall length (Jeswiet et al. 2005). Hirohiko also developed a new technique to form asymmetric shapes by controlling the spinning roller path to follow the mandrel shape as the force controlled (Arai 2005). The process suggested by Hirohiko which called robotic metal spinning still needs a very good control of the roller force by means of robots arm may be, and the wall thickness reduction in this process was relative to the mandrel inclination angle (Arai 2005). Hirohiko developed a new process from the previous mentioned process by using linear motors and replaced the closed loop control by an open loop control for the force control, this process still needs very accurate control and does not has the ability of reducing the wall thickness by high ratios in one pass(Arai 2006).

The shear and tube spinning process differs from the conventional spinning process in which the wall thickness reduction is mandatory(Heinz Tschaetsch 2004).

The flow forming process is the process in which the wall thickness is reduced by a specific value for the cup shape hollow products(Danno 2013). However the shear spinning process is the process of forming aconical shape and reduce its wall thickness relative to the cone angle (Danno 2013).

Lossen and Homberg developed the friction spinning technique which differs from the conventional spinning in which the roller forced to rotate in an opposite direction of the mandrel rotation direction which generates heat from the friction between the roller and the specimen (Lossen and Homberg 2014). The new friction spinning technique was investigated and found to be useful to increase the forming limits of the spinning ratio and the wall thickness reduction. Also, it can control the hardness adjustment as described by Lossen and Homberg (Lossen and Homberg 2014). But, the new friction spinning technique still performing the process of wall thickness reduction after the spinning process in another pass.

In the area of developing or modifying the wall thickness reduction process; Prakash and Singhal modified the shear spinning process to produce a new tool assembly which has the ability of performing a shear spinning for long tubes. The new tool suggested by Prakash and Singhal found to be successful with long tubes as long as 10 m, and with small diameters of about 30 mm for stainless steel AISI-304 and the reduction in wall thickness reached 80%(Prakash and Singhal 1995) but the thickness reduction process performed on a tube not a flat blank spun and thickness reduced in one pass. Also, Luo et al. developed a compound process to perform a wall thickness reduction and filling inner ribs with the aid of machines have a numerical control (Luo et al. 2018). This process developed by Luo et al.(Luo et al. 2018)was combining counter-roller spinning, multi-neck spinning, and hot spinning however the process still does not perform the conventional and wall thickness reduction in one pass.

Birk proposed the use of ball in the spinning process to reduce or increase the diameter of tubes, adapted from (Kuss and Buchmayr 2015). This process was recently developed to perform the tube thickness and force it to fill in ribsat the mandrel to form a tube with inner ribs as concluded by Abd-eltwab et al.(Abd-eltwab et al. 2017). These investigations in the area of using balls to perform shear spinning or flow forming leads us to use the balls in the wall thickness reduction in the present work.

Obviously, the manufacturing process of a thin wall cup with a high thickness reduction ratio of about 75% never done before in one pass by spinning. The objective of this research is to manufacture a thin wall cup from a metallic blank

in one pass, manufacturing a tool which can perform the new suggested technique and test both the tool and the products.

NEW TECHNIQUE DESCRIPTION

The compound process is schematically shown in Figure 1. The upper part of the figure is the process before forming and the lower part is during the forming process. The compound process is performed by a roller conducting the conventional spinning followed by a ball, giving rise to the reduction of the wall thickness. This means that, the two processes are conducted in one stroke with time saving of about 40% of the two processes time if conduced in series.

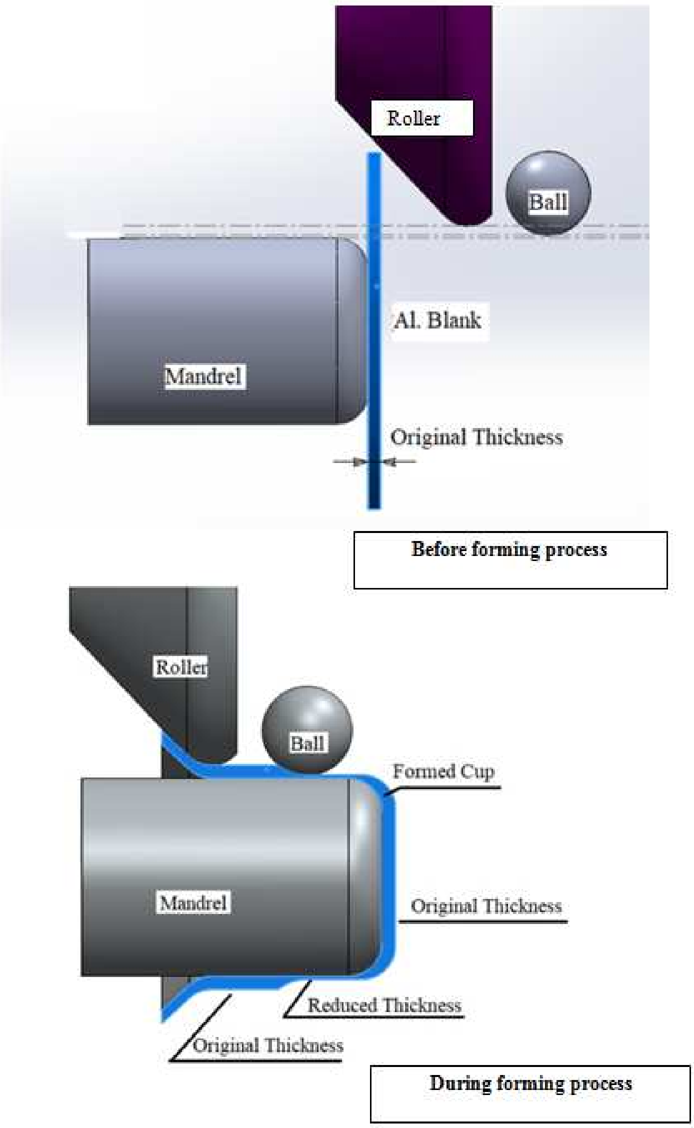
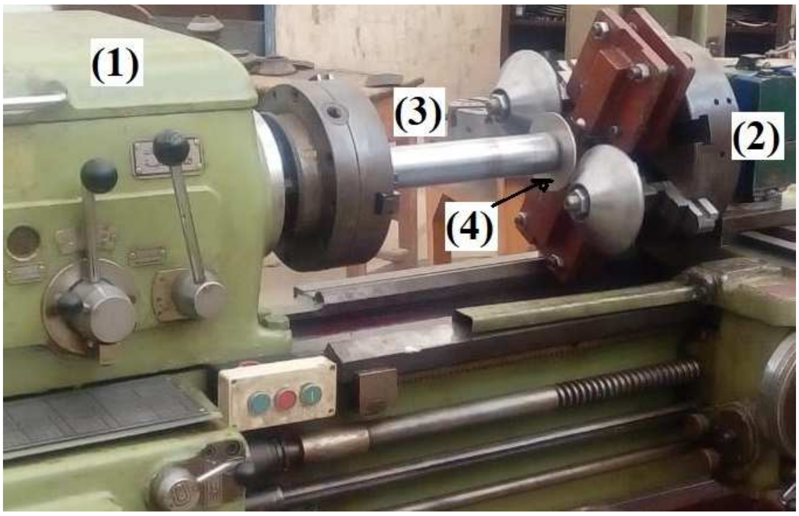


Figure 1: Schematic for a New Spinning Process to Form the Thin Wall Cup in One Stroke

EXPERIMENTAL SETUP

The setup of the experiments is shown in figure 2. The setup consists of the new tool [2]which is attached to the lathe carriage, the lathe machine[1], the mandrel[3] which is attached to the lathe chuck, and the blank[4] which is attached to the mandrel. The new tool was designed to let the rollers rotate freely about its axis which is parallel to the lathe machine axis or mandrel axis. Also, the balls can freely rotate about its center in the three axes. The free rotation of the

rollers and the balls can reduce the force induced by the friction during the forming process. The blank material was Aluminum with yield strength of 66 MPa, strength coefficient of 141 MPa, and strain hardening exponent of 0.27.



1	Lathe machine	3	Mandrel
2	New Tool	4	Al. Blank

Figure 2: Experimental Set-Up of the Compound Process

New Compound Tool Working Theory

The new tool depends on the idea of performing the conventional spinning process by rollers followed by balls which will perform the wall thickness reduction [flow forming process]. The tool is shown in figure 3. The new tool mainly consists of two rollers performing the conventional spinning and two balls performing the wall thickness reduction. The assembly of the two rollers and two balls are mounted on jaws of separate lathe chuck with four independent jaws the separate chuck service as a tool holder. The rollers are at a front level mentioned [1] in figure 4 and a second level mentioned [2] in figure 4 following the rollers level by about 5 mm is the balls level. The blank is attached to the mandrel on the lathe chuck. The assembly of the tool is fed toward the blank and mandrel, the rollers touches the blank first and start to perform the conventional spinning process. After a travel of 5 mm the balls starts to touch the formed part of the blank to perform the flow forming process and reduces the wall thickness at the same stroke.

Figure 3: The Complete New tool

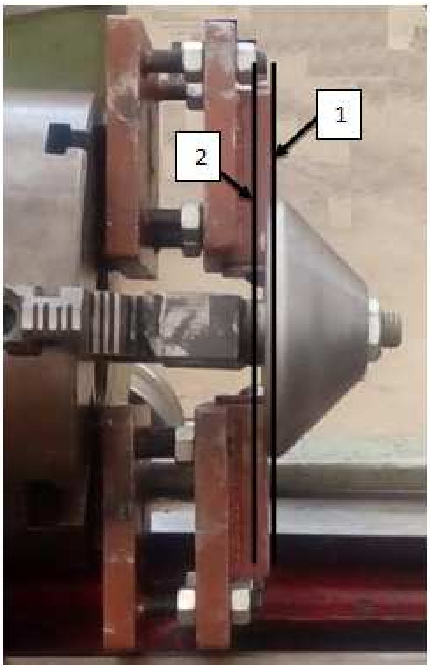


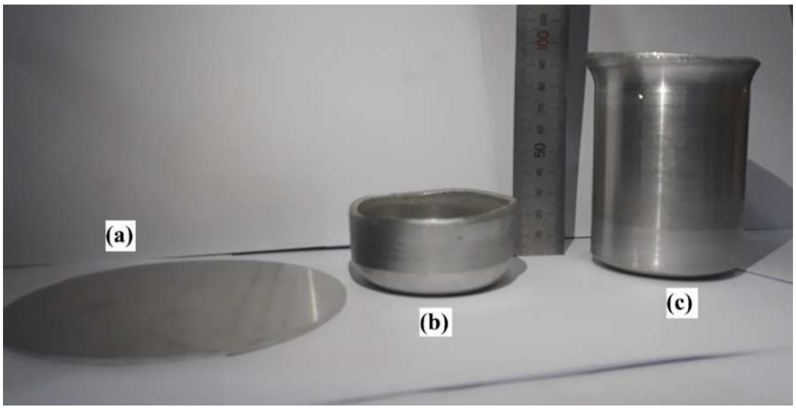
Figure 4: The Complete New Tool with Levels Clarified

EXPERIMENTAL WORK

The experimental work is mainly aims to test the ability of the new compound tool of performing the process and produces a thin wall cup successfully. The blank thickness was selected to be 4 mm. The blank diameter which also identifies the spinning ratio [ratio of the blank diameter to the mandrel diameter] was selected from 100 to 120 mm with step 5 mm to check different spinning ratios. The mandrel rotational speed was selected to be 230 RPM and the feed rate was 0.3 mm/rev. The blank material was Aluminum as received from the local market and was annealed before the experimental work due to residual stresses from rolling and cutting the blanks from the sheet. The annealing process was performed by heating the blanks to a temperature of 450^{o}C for two hours and let it cool to the room temperature inside the furnace, this process takes about 24 hours. The blank is fixed with the mandrel which was tightened on the lathe chuck to give it the ability of rotation with the chuck. The new tool is fastened on the lathe carriage in the place of the lathe tool post to give the tool the ability of automatic feeding toward the blank. The clearance between the mandrel and the rollers was adjusted by moving the jaws toward the mandrel by means of the jaws screw, this clearance is equal to the blank thickness. The balls cross in-feed toward the mandrel was adjusted by the movable jaws carrying the balls, and it was adjusted to 1 mm which means a reduction ratio in thickness equal 75%. After the tool was adjusted; the process started with running the lathe to give the mandrel the required rotational speed, the tool takes its feed rate from the movement of the carriage toward the blank. The rollers perform the conventional spinning and the balls takes place in the process after the rollers by about 5 mm. the conventional and flow forming spinning processes are performed consequently at one stroke. After performing the compound process, the tool was retreated to its initial place and the final cup was removed from the mandrel.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The experiments with the new compound tool verified the success of the tool to perform the compound process as shown in Figure 5. The figure represents the stages of the blank forming from a straight blank mentioned [a] in Figure 5 to a conventional formed cup mentioned [b] and then a thin wall cup mentioned [c] in Figure 5. The experiments were performed for different diameters from 100 to 120 mm with step 5 mm. All diameters were successfully formed except the blank with diameter of 120 mm was failed. The shown successful cup in Figure 5 was a blank of diameter 115 mm.



(a) The blank (b) The conventional formed cup
(c) The cup after shear spinning

Figure 5: Photograph for the Process Stages

Figure 6 represents the successful cups with different diameter from 100 to 115 with step of 5 mm, all mentioned cups were successfully formed with the new tool at a rotational speed of 230 RPM and a feed rate of 0.3 mm/rev. The experiments were performed 4 times for every diameter and the shown cups are selected from the experiments.

(a) The blank diameter 100 mm (b) The blank diameter 105 mm
(c) The blank diameter 110 mm (d) The blank diameter 115 mm

Figure 6: Photograph of Successful Products with Different Diameters

The unsuccessful cups of diameter 120 mm were shown in Figure 7. The diameter of 120 mm was tested 4 times to be sure of the result. The shown cups in Figure 7 are selected from many cups were tested. The process with high spinning ratio of 2 could not be completed and the blank failed to be formed as shown in Figure due to the high spinning ratio which increases the tension stresses in the blank.

Figure 7: Photograph for Failed Products with Blank Diameter 120 mm

To verify the tool success in the area of wall thickness reduction; a thickness variation along the cup wall was conducted. The thickness of the cup wall was measured at ten points distributed equally along the wall as shown in Figure 8. The thickness variation along the cup wall found to be did not exceed ±0.014 mm from the required thickness of 1 mm which was identified by the clearance between the balls and the mandrel. This resultis quite enough to verify the tool success as mentioned before.

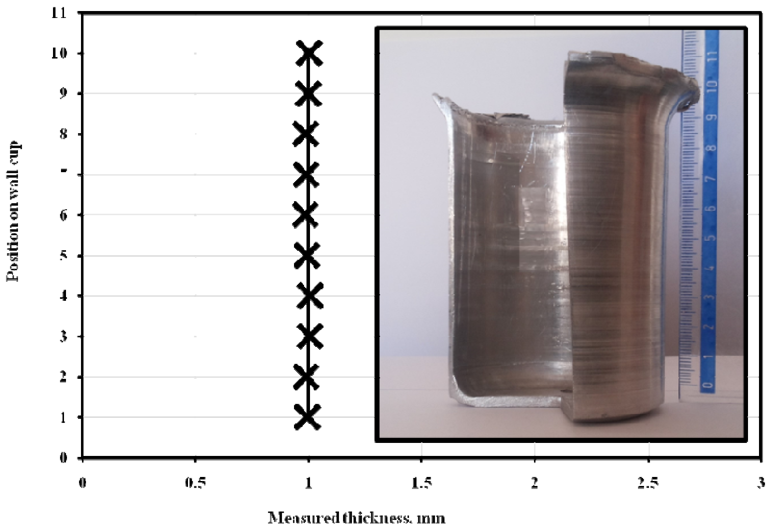


Figure 8: The Thickness Variation Along the Wall Cup

CONCLUSIONS

From the experimental work the following conclusions can be obtained:

- The process is a new simple and low-tooling cost process, it is true, time and money saving when compared to conventional processes.
- The compound tool is successful with spinning ratio limited to 1.92 which is a great spinning ratio. However, the process needs more investigation in the area of maximum spinning ratio.
- The tool is successful to a reduction ratio of 0.75 which is an accepted reduction ratio for many products. But, this is not the maximum achievable reduction ratio by the process.

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REFERENCES

1. *Abd-eltwab, Ayman A, S Z El- Abden, Khaled I E Ahmed, Ragab K Abdel-magied, and M.N. El-Sheikh. 2017. "An Experimental and Theoretical Investigation into Deformation of Internally-Spline Sleeves." Research Journal of Applied Sciences, Engineering and Technology 14 (11): 436–44. https://doi.org/10.19026/rjaset.14.5145.*
2. *Arai, Hirohiko. 2005. "Robotic Metal Spinning - Forming Non-Axisymmetric Products Using Force Control." Proceedings - IEEE International Conference on Robotics and Automation 2005 (April): 2691–96.*

   https://doi.org/10.1109/ROBOT.2005.1570520.
3. *Arai, Hirohiko. 2006. "Force-Controlled Metal Spinning Machine Using Linear Motors." Proceedings - IEEE International Conference on Robotics and Automation 2006 (May): 4031–36. https://doi.org/10.1109/ROBOT.2006.1642321.*
4. *Bewlay, B P. 2006. "Spinning." ASM Handbook, Volume 14B, Metalworking: Sheet Forming 14B: 9.*
5. *Boljanovic, Vukota. 2004. Sheet Metal Forming Processes and Die Design. Industrial Press New York.*
6. *Danno, Atsushi. 2013. Handbook of Manufacturing Engineering and Technology. Springer-Verlag London. https://doi.org/10.1007/978-1-4471-4976-7.*
7. *Heinz Tschaetsch. 2004. Metal Forming Practise. Chemistry & Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/3-540-33217-0.*
8. *Jeswiet, J., F. Micari, G. Hirt, A. Bramley, J. Duflou, and J. Allwood. 2005. "Asymmetric Single Point Incremental Forming of Sheet Metal." CIRP Annals - Manufacturing Technology 54 (2): 88–114. https://doi.org/10.1016/S0007-8506(07)60021-3.*
9. *Alavala, Chennakesava R. "Effect of Temperature, Strain Rate and Coefficient of Friction on Deep Drawing Process of 6061 Aluminum Alloy." International Journal of Mechanical Engineering 5, no. 6 (2016): 11-24.*
10. *Kuss, M., and B. Buchmayr. 2015. "Analytical, Numerical and Experimental Investigations of a Ball Spinning Expansion Process." Journal of Materials Processing Technology 224: 213–21. https://doi.org/10.1016/j.jmatprotec.2015.05.010.*
11. *Lossen, Benjamin, and Werner Homberg. 2014. "Friction-Spinning - Interesting Approach to Manufacture of Complex Sheet Metal Parts and Tubes." Procedia Engineering 81 (October): 2379–84. https://doi.org/10.1016/j.proeng.2014.10.337.*
12. *Saravanan, S., Saravanan, M., & Jeyasimman, D. (2018). Study on Effects of Spring Back on Sheet Metal Bending Using Simulation Methods. International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), 8(2), 923-932p.*
13. *Luo, Wei, Fei Chen, Binbin Xu, Zhaojun Yang, Yaming Guo, Bo Lu, Tao Huang, and Fei Chen. 2018. "Study on Compound Spinning Technology of Large Thin-Walled Parts with Ring Inner Ribs and Curvilinear Generatrix."*
14. *Prakash, Rajnish, and R. P. Singhal. 1995. "Shear Spinning Technology for Manufacture of Long Thin Wall Tubes of Small Bore." Journal of Materials Processing Tech. 54 (1–4): 186–92. https://doi.org/10.1016/0924-0136(95)01940-5.*
15. *Semiatin, S L, Air Force, and Manufacturing Directorate. 2005. ASM Handbook: Metalworking: Bulk Forming. Vol. 14A. https://doi.org/10.1361/asmhba0003971.*